Corn Storage

REPORT OF COOPERATIVE RESEARCH ON INSECT CONTROL IN FARM STORED GRAIN

No. 5 Period--July 1 to September 30, 1942

R. T. Cotton

CORN STORAGE

Effect of Temperature on Insect Abundance in the Commercial Corn Area*

During August, all of the experimental bins in the commercial corn area were sampled, and observations made on temperatures, changes in quality, and insect infestations. In general there has been but little change in the quality of the corn stored in these bins. The moisture content of the surface grain has shown a general decrease over the entire area since the March, 1942, sampling, and a general increase in insect infestation was noted. Dangerous insect infestations were noted in but two localities--Richardson County, Nebraska, and Henry County, Iowa. The increase in insect population was more marked in the southern portion of the commercial corn area, due chiefly to larger initial populations in the spring, and also to higher grain temperatures. A comparison of the mean bin temperatures taken in a vertical column in the center of the bin is presented in table 1. It may be noted in the table that in October, 1941, mean bin temperatures ranged from 62° F. in Roberts County, South Dakota, (the most northerly observation point) to 82° F. in Henry County, Iowa, (the most southerly point then under observation). By March, 1942, mean bin temperatures had dropped to 30° F. in the northern locality and to 43° in the Henry County location. Observations taken during August, 1942, showed that there had been a general rise in mean bin temperatures of about 30° F. over the entire area, the means ranging from 58° in Roberts County, South Dakota, to 75° in Henry County, Iowa. In the latter locality, insect infestation had caused abnormally high temperatures in two of the bins, and these are included in the average for the locality.

---

* Reported by H. H. Walkden, J. M. Magner, in cooperation with the Bureau of Agricultural Chemistry and Engineering and State Entomology Departments of the several States in the Commercial Corn Area.

Table 1: -- Average temperatures of shelled corn in the centers of steel bins in the commercial corn area, October, 1941, to August, 1942.

County	State	No. of bins	Mean temperatures Center of bins (°F.) Oct., 1941	March, 1942	Aug., 1942
Roberts	So. Dak.	3	62	30	58
Minnehaha	" "	3	64	37	64
Yellow Medicine	Minn.	10	66	32	64
Nicollet	"	8	66	33	63
Antelope	Nebr.	12	68	38	73
Richardson	"	7	74	39	75
Osceola	Iowa	12	64	34	64
Cerro Gordo	"	6	67	36	60
Montgomery	"	11	69	39	68
Henry	"	10	82*	43	75*
Whiteside	Ill.	8	No record	39	70
LaSalle	"	8	" "	38	69
Henderson	"	8	" "	41	72
Iroquois	"	8	" "	42	72
Sangamon	"	8	" "	42	73
Champaign	"	8	" "	42	74
Total		130			

* High temperatures in two bins caused by insect infestation.

The insect infestation in the various bins in August, 1942, is given in table 2. The samples were all taken in the same manner, and the results of the examination show that insect infestations are much greater in the southern portion of the area, and also that nearly three-fourths of the insects are located in the upper portion of the bins. Such a distribution is quite probably due to a definite temperature reaction on the part of the insects, since the warmest portion of the grain is in the upper part of the bin, both in the summer and winter months.

Table 2: -- Insect infestation in shelled corn stored in steel bins in the commercial corn area, August, 1942.

Location		Bins	No. of insects found in samples					
		sam-	Upper half		Lower half		Total	Percent
County	State	pled	Live	Dead	Live	Dead	insects	living
Northern Section								
Roberts	So. Dak.	3	3	0	0	0	2	100.0
Minnehaha	" "	3	39	63	1	11	114	35.1
Yellow Medicine	Minn.	10	11	283	1	33	328	3.7
Nicollet	"	8	103	52	10	5	170	66.5
Antelope	Nebr.	12	365	105	157	64	691	75.5
Osceola	Iowa	11	78	303	2	12	395	20.3
Cerro Gordo	"	6	192	170	26	65	453	48.1
Totals for Section		53	790	976	197	190	2153	45.8
Southern Section								
Richardson	Nebr.	6	358	127	422	164	1071	72.8
Montgomery	Iowa	10	120	198	81	81	480	41.9
Boone	"	8	662	275	25	18	980	70.1
Henry	"	10	423	2759	339	645	4166	18.3
Whiteside	Ill.	8	205	126	19	54	404	55.4
Henderson	"	8	147	164	68	45	424	50.7
LaSalle	"	4	17	37	3	11	68	29.4
Sangamon	"	6	50	88	42	51	231	39.8
Iroquois	"	8	186	417	52	491	1146	20.8
Champaign	"	8	25	525	6	174	730	4.3
Totals for Section		76	2193	4716	1057	1734	9700	33.5
Totals for Area:		129	2983	5692	1254	1924	11853	35.7
Percentage of living insects found in upper half of bins ---- 70.4								

The comparative abundance of the 15 species of stored grain insects found in the samples taken during August is given in table 3. It may be seen that the sawtooth grain beetle was the most abundant species, with the flat grain beetle next in numbers. It is of interest to note the rather large number of dermestids found in the grain, and also the scarcity of the rust red flour beetle.

Table 3: -- Relative abundance of the various species of insects found in shelled corn stored in steel bins in the Northern and Southern sections of the commercial corn area, August, 1942.

Species	Number of insects		Total for region
	Northern section	Southern section	
Sawtoothed grain beetle	460	2224	2684
Flat grain beetle	370	758	1138
Dermestids	39	74	113
Typhaea stercorea	40	46	86
Cynaeus angustus	14	58	72
Indian meal moth	32	13	45
Foreign grain beetle	6	26	32
Rust red flour beetle	0	21	21
Cadelle	0	19	19
Rice weevil	6	5	11
Small-eyed flour beetle	0	4	4
Granary weevil	0	3	3
Black flour beetle	1	0	1
2-Banded fungus beetle	0	1	1
Yellow meal worm	0	1	1
Totals	968	3253	4231

Special Studies on Insect Infestation in Corn in Illinois*

Insect infestation records are based on samples taken from experimental bins in six counties in the northern half of Illinois since samples from turning and cleaning rigs are no longer being sent to the office. Sampling records show that in all six counties the sawtooth grain beetle, Oryzaephilus surinamensis and the flat grain beetle, Laemophloeus minutus are the two most abundant insects. These are followed by the rust-red flour beetle, Tribolium castaneum; cadelle, Tenebroides mauritanicus; foreign grain beetle, Ahasverus advena; and Cynaeus angustus in much small numbers. Cynaeus angustus was recorded only from Henderson and Whiteside counties.

The Indian meal moth, Plodia interpunctella, has continued in about the same numbers. No large immediate build-up seems evident, although a few scattered bins have a large enough population to cause webbing on the grain surface.

Hymenopterous beetle parasites build up to large populations during the summer and early fall.

The lesser grain borer, Rhizopertha dominica, was recorded in farm-stored wheat samples from Bond, Clinton, and Monroe counties, Illinois.

Temperature Changes

The temperature of steel-bin corn has followed the same general trend as during the past year with the exception that the rise this year was not as rapid or as high as last year. This may be attributed, no doubt, to the lower air temperature during the summer of 1942 over 1941. Temperatures in steel-bin corn had begun to drop by mid September.

Temperature readings, moisture sample records and insect records for bin 104 at Thomasboro, Illinois, for the past six months are shown in the following tables:

---

* Reported by J. M. Magner in Cooperation with Illinois State Entomology Department.

Table 4: -- Temperature changes in corn in various parts of experimental bin No. 104 (2750 Butler) at Thomasboro, Illinois, from February 9, 1942, to September 23, 1942.

Date of reading	Thermocouple readings in various parts of bin														
	Center of bin					Average of thermocouple readings in ring 3' from center					Average of thermocouple readings in ring 6' from center				
	Height from floor					Height from floor					Height from floor				
1942	0'	3'	6'	9'	12'	0'	3'	6'	9'	12'	0'	3'	6'	9'	12'
2-9	43	44	46	48	33	41	37	40	43	35	37	34	35	34	31
2-25	41	40	42	44	32	40	38	39	41	32	39	35	36	34	31
3-20	40	39	39	41	46	31	37	38	38	41	42	36	36	48	49
4-3	43	40	41	41	58	44	40	40	40	46	45	41	40	42	44
4-20	40	37	38	39	49	48	39	38	40	50	58	42	42	45	48
5-6	49	39	40	48	68	64	41	41	46	61	74	49	47	57	60
5-23	54	40	42	53	59	67	51	47	53	47	74	52	50	56	60
6-8	58	45	48	62	81	74	49	52	60	81	82	61	60	71	77
6-27	61	48	53	65	75	73	54	57	66	74	78	64	64	71	72
7-10	65	54	59	69	81	74	65	62	70	82	81	69	69	76	82
7-27	65	59	65	75	93	75	63	67	76	88	81	72	74	82	86
8-7	70	65	70	79	85	77	73	71	79	87	84	77	78	83	88
8-20	69	66	71	82	79	76	70	73	82	85	80	76	73	82	84
9-23	63	66	68	78	64	75	74	76	81	75	79	75	76	79	77

Table 5: -- Vertical moisture record on experimental bin 104, Thomasboro, Illinois, April 3, 1942, to September 23, 1942.

Date (1942)	1*	2	3	4	5	6
4-3	16.38	17.71	15.51	12.06	11.33	11.19
4-20	14.22	14.48	15.68	13.84	11.58	11.23
5-6	12.28	14.28	15.34	12.62	11.65	11.17
5-23	12.81	14.92	15.06	12.06	11.68	11.43
6-8	12.06	13.59	12.26	13.16	11.88	11.68
6-27	11.00	12.04	14.56	13.03	11.65	11.45
7-10	11.45	13.35	14.67	12.46	11.82	11.63
7-27	10.88	11.36	12.84	12.31	11.56	11.68
8-7	11.10	11.98	13.14	12.41	11.66	11.66
8-20	11.96	12.98	14.54	13.41	11.96	11.42
9-23	12.61	13.41	14.45	13.40	11.94	12.01

* Numbers at column heads indicate cell numbers of five-foot grain probe starting with number one at the handle and reading down. Five probe samples taken with five-foot grain probe at center of bin.

Table 6: -- Insect infestation in experimental bin 104, Thomasboro, Illinois, March 20, 1942, to September 23, 1942

Date	Rust-red flour beetle	Foreign grain beetle	Sawtooth grain beetle	Flat grain beetle	Typhaea stercorea	Cadelle	Anthocorids	Hymenopterous parasites	Grain mites	Booklice	Larvae
3-20	4D*										4
4-3		1D		1						3	
4-20		2D			2D						
5-6	2D				2D						
2-23		1D									
6-8				2						2	
6-27				16	4						
7-10			1	1							
7-27				31							1
8-7	7D		9	2						5	
8-20			1	14						10	2
9-23	3		15	254		1	1	3	1	2	4

* - D = Dead

Five probe samples with five-foot grain probe at center of bin.

Turning and screening

All turning and screening of steel-bin corn was stopped during the early part of this quarter. Practically all of the corn remaining in the state has been turned and screened, and the small percentage not turned and screened is being sold.

Some wheat has been stored in steel bins in the central and southern parts of the state. Much of this has needed fumigation shortly after being placed in steel bins.

Empty bins throughout the state are being prepared to take soybeans within the next few weeks.

Special Studies

Since the last report one more observation was made on bins equipped with "Sisalcraft" paper covers. The surface condition of the grain at the Buckley and Claytonville bin sites was such that the covers were removed to prevent further spoilage of the corn. The covers were allowed to remain on the bins at Loda, Illinois, as no indication of spoilage was evident in those bins which had been turned and cleaned shortly before the covers were placed over the grain.

Bins 67, 69, and 72 at Claytonville and 1037, 1038, and 1039 at Buckley all had wet, moldy corn two to eight inches deep in an area from ten to sixteen feet in diameter. It was necessary to remove approximately thirteen bushels of spoiled corn from each of the three bins at Buckley.

Temperature, moisture, and insect records are shown in table 7. Temperatures are based on the average of readings at four depths (five depths for Buckley bins) at center of the bins, and percentage moisture is based on the average of the top three cells of a five-probe sample taken at the eenter of the bin.

The insect records are based on the actual count of live insects found in a five-probe sample. All samples were taken with a five-foot grain probe.

A more extensive study was made on seven bins which included 2000- and 2,750-bushel capacities, covered, uncovered, cleaned, and uncleaned corn. In these bins moisture samples were taken the full depth of each bin and at four separate areas beginning at the center and extending to within one foot of the side wall at three and one-half foot intervals. In all, eighty-eight cell samples were taken in each bin. After tabulating the results, it was found that there was very little difference in the percent moisture of the corn throughout the bin beyond the first foot below the surface. Even those bins which contained spoiled corn on the surface followed the same pattern as normal bins below the top three probe cells.

Table 7: -- Temperature, moisture, and insect records on bins covered with Kraft paper.

Buckley, Illinois				Claytonville, Illinois				Loda, Illinois			
Bin	Temp. (°F)	Moisture	Insects	Bin	Temp. (°F)	Moisture	Insects	Bin	Temp. (°F)	Moisture	Insects
1037	75	15.55	13	65	73	12.39	14	242	70	10.98	1
1038	75	16.06	1	66	69	13.74	23	243	70	12.22	1
1039	75	17.18	-	67	71	13.79	81	244	68	11.75	-
1040	68	13.63	13	69	68	13.76	4	245	72	12.69	-
1041	69	12.95	10	72	68	13.43	41	580	68	12.31	-
1042	68	13.12	23	76	74	13.07	64	581	70	10.99	-
								582	71	12.15	-
								583	71	11.26	-

Bins covered:

Buckley - 1037, 1038, and 1039
Claytonville - 67, 69, and 72
Loda - 242, 243, 245, 582, and 583

Bin No. 244 (Loda) has paper through center of grain mass.

Fumigation of corn

Experimental work on the fumigation of corn was carried on both in Illinois and Iowa.

Fumigation experiments in Illinois*

During the quarter ninety steel bins containing corn were fumigated experimentally. The results of these fumigations are shown in tables 8 and 9.

In fumigations B, C, D, E, and F, shown in table 8, the amount of fumigant shown in column four was added to the carrier, which in all cases was carbon tetrachloride, to make the total amount per 1,000 bushels shown in column six. In "Ethide" fumigation G the two and one-half pounds were added to one gallon of carbon tetrachloride for each 1,000 bushels.

With the exception of fumigation H, in which the fumigant was hand-sprinkled over the grain surface, all fumigants were applied with a rotary pump at twenty-five pounds pressure through a one-eighth inch discharge hole to insure uniform sprinkling over the grain surface.

Special fumigations

In an effort to check methods of application of fumigants, several tests were run in which the fumigating material was applied to the grain surface in three different ways:

A. Applied in a two-foot band around the outer edge of the grain surface.

B. Applied in a four-foot diameter circle at the center of the grain surface.

C. Applied uniformly over the entire grain surface.

Based on the results shown in table 9, application of fumigants uniformly over the grain surface in steel bins still appears to be the best method.

---

* Reported by J. M. Magner in Cooperation with Dr. M. D. Farrar, Research Entomologist, Illinois State Natural History Survey.

Table 8: -- Fumigation experiments

Series	Number of bins	Material applied for each 1,000 bushels of shelled corn in steel bins: Fumigant	Amount	Other	Amount to make total of	Grain temperature. °F at three-foot intervals from floor: Floor	3-ft.	6-ft.	9-ft.	Position of probe	Average number of live insects in six check cells after fumigation, compared with unfumigated control cells--second figure.: Rust-red flour beetle	Rice weevil	Granary weevil	Lesser grain borer	Saw-toothed grain beetle	Flat grain beetle	Beetle larvae	Hymenopterous parasites
										D*	0-57	0-42	0-1.5	0-91	0-1	0-130	0-14	0-9
A	10	Br 10	2 gal.			60	61	68	83	S	0-46	0-39	0- .5	0-74	0-.5	0-212	0-17	0-8
										D	.9-66	0-34	0-3	0-131	0-2	0-359	0-27	0-17
B	10	CCl_3NO_2	1 lb.	CCl_4	1 gal.	62	62	67	80	S	3.5-48	.1-29	0-1	.1-68	0-0	0-126	.3-25	.2-11
										D	.1-48	0-42	0-2	0-82	0-2	0-162	0-13	0-9
C	10	CCl_3NO_2	1½ lb.	CCl_4	1 gal.	58	62	72	89	S	0-44	0-49	0-0	0-80	0-1	0-297	0-9	0-5
										D	.9-58	.1-94	0-1	0-115	0-5	.7-596	1.1-40	.3-9
D	10	Ethide	1½ lb.	CCl_4	1 gal.	59	63	73	83	S	.7-44	0-51	.6-2	0-92	0-1	2.3-404	.6-50	.6-28
										D	.07-58	0-47	.6-48	.2-134	0-3	12.5-539	1.2-43	.7-13
E	15	Ethide	2 lb.	CCl_4	1 gal.	61	66	75	86	S	2.3-46	.07-56	1.8-20	1.8-94	0-5	12.5-355	1.2-64	.7-18
										D	0-63	0-134	0-0	0-160	0-0	0-160	0-26	0-13
F	4	Ethide	2½ lb.	CCl_4	1 gal.	59	66	75	81	S	.25-58	.25-167	0-0	.25-132	0-2	.25-775	.25-23	0-17
										D	0-13	0-108	0-0	0-109	0-1	0-285	0-11	0-3
G	6	Ethide	2½ lb.	CCl_4	1¼ gal.	67	72	78	81	S	0-9	0-111	0-0	0-94	0-1	0-310	0-12	0-5
										D	3-13	21-108	0-0	14-109	.2-1	41-285	2-11	1-5
H	4	Ethide	3½ lb.	CCl_4	4½ lb.	66	72	77	79	S	2-9	11-111	0-0	10-94	.2-1	23-310	1.2-12	.2-5

* D = Diagonal eleven-foot grain probe placed toward center of floor.

S = Side-wall probe slanted to strike floor near the junction of side wall and floor.

Table 9: -- Fumigation experiments to determine best method of application.

Series Number of bins	Material applied for each 1000 bu. of shelled corn in bins: Fumigant	Amount	Grain temperature °F at three-foot intervals from floor: Floor	3-ft.	6-ft.	9-ft.	Position of probe	Average number of live insects in six check cells after fumigation, compared with unfumigated control cells--second figure. Rust-red flour beetle	Rice weevil	Granary weevil	Lesser grain borer	Sawtoothed grain beetle	Flat grain beetle	Beetle larvae	Hymenopterous parasites
							D*	4-66	3-134	0-0	8-160	0-0	15-1035	2-26	1-13
A2	Br 10 Mix	2 gal.	60	68	77	87	S	15-48	25-167	0-0	25-132	1-2	60-775	4-23	3-17
							D	4-66	8-134	.5-0	10-160	0-0	52-1035	4-26	0-13
B2	Br 10 Mix	2 gal.	60	67	77	90	S	8-58	9-167	0-0	30-132	0-0	80-775	4-23	1-17
							D	0-66	0-134	0-0	0-160	0-0	0-1035	0-26	0-13
C2	Br 10 Mix	2 gal.	59	68	77	88	S	0-58	0-167	0-0	0-132	0-0	0-775	0-23	0-17
							D	.5-25	.5-126	0-0	3-154	0-0	2-372	1-14	0-10
A4	Br 10-S	1½ gal.	64	72	79	82	S	1.2-32	.7-163	0-0	14-183	0-0	5-451	1-22	0-13
							D	1.5-25	.5-126	0-0	1.5-154	0-0	.5-372	.5-14	0-10
B4	Br 10-S	1½ gal.	70	75	80	83	S	9.5-32	14-163	0-0	31-183	0-0	25-451	6-22	.5-13
							D	0-25	0-126	0-0	0-154	0-0	0-372	0-14	0-10
C4	Br 10-S	1½ gal.	64	71	80	82	S	0-32	0-163	0-0	0-183	0-0	0-451	0-22	.3-13
							D	0-25	0-126	0-0	0-154	0-0	0-372	0-14	0-10
A1	Br 10-S	2 gal.	64	73	81	86	S	0-32	0-163	0-0	0-183	0-0	0-451	0-22	1-13
							D	0-25	0-126	0-0	0-154	0-0	0-372	9-14	0-10
B1	Br 10-S	2 gal.	64	72	78	79	S	1-32	4-163	0-0	13-183	0-0	2-451	0-22	2-13
							D		0-126	0-0	0-154	0-0	0-372	0-14	0-10
C1	Br 10-S	2 gal.	64	71	78	77	S		0-163	0-0	13-183	0-0	2-451	0-22	2-13

Br 10 Mix = A mixture of Dowfume Br 10 and Dowfume 75.
Br 10-S = Propylene dichloride, carbon tetrachloride (3-1), methyl bromide (10%).
* - D = Diagonal eleven-foot grain probe placed toward center of floor.
S = Side wall probe slanted to strike floor near the junction of side wall and floor.

Fumigation Experiments in Iowa*

The relative toxicity of a number of fumigant mixtures was determined for the fumigation of corn bins. The results obtained are summarized in table 10.

Table 10: -- Summary of the results obtained in experimental fumigation of corn, Ames, Iowa, September, 1942.

Bin No.		Bushel capacity	Date treated	Dosage per 1000 bu.	Amount used	Kill (%)	Remarks
			Dowfume Br-10				
Ogden	259	2000	9-8	2 gals.	4 gals.	99	
"	260	2000	9-8	1 "	2 "	99	
Boone	299	2740	9-8	1 "	2.75 "	99	
"	409	2740	9-8	1 "	2.75 "	100	
"	305	2740	9-8	2 "	5.5 "	100	
"	308	2740	9-8	2 "	5.5 "	99	
			Dowfume Br-10-S				
Ellsworth	577	2000	9-16	1 gal.	2 gals.	50	
"	579	2000	9-16	2 gals.	4 "	81	
Kamrar	789	2740	9-22	2 "	5.5 "	99	
"	790	2740	9-22	2 "	5.5 "	99	
"	1136	2740	9-22	1 "	2.75 "	78	
"	1142	2740	9-22	1 "	2.75 "	94	
			Dowfume E				
Kelley	172	2000	9-21	2 gals.	4 gals.	80	
"	175	2000	9-21	1 "	2 "	34	
Roland	702	2740	9-22	2 "	5.5 "	84	
"	703	2740	9-22	2 "	4 "	93	2400 bu. grain
"	704	2740	9-22	2/3 "	1.75 "	50	Lack of fumigant
Ellsworth	622	2740	9-16	1 "	2.75 "	85	
			Dowfume P				
Ogden	113	2000	9-10	2 gals.	4 gals.	100	1 insect surviving
"	287	2000	9-10	1 "	2 "	100	
Kelley	185	2740	9-11	1 "	2.75 "	97	
Boone	414	2740	9-11	1 "	2.75 "	92	
"	302	2740	9-11	2 "	5.5 "	98	
Ogden	464	2740	9-10	2 "	5.5 "	100	1 insect surviving
			Dowfume C				
Ellsworth	275	2000	9-16	1 gal.	2 gals.	100	
"	576	2000	9-16	2 gals.	4 "	97	

(continued)

* Reported by H. H. Walkden.

Table 10 (continued)

Bin No.	Bushel capacity	Date treated	Dosage per 1000 bu.	Amount used	Kill (%)	Remarks
		Methylene Chloride Mixture				
McCallsburg 201	2000	9-15	1 gal.	2 gals.	96	
" 200	2000	9-15	2 gals.	4 "	100	1 insect surviving
Zearing 768	2740	9-15	1 gal.	2.75 "	99	
" 769	2740	9-15	1 "	2.75 "	90	
" 770	2740	9-15	2 gals.	5.5 "	100	
" 771	2740	9-15	2 "	5.5 "	100	1 insect surviving

On the basis of the data obtained, the dosages for the different Dow mixtures are given below:

Table 11: -- Dosages.

Fumigant*	No. gallons per 1000 bushels		
	Size of bin		
	1000-bushel	2000-bushel	2740-bushel
Dowfume 75	6	5	4-5
Dowfume Br-10	2	2	2
Dowfume Br-10-S	2	2	2
Dowfume C	More than 2	2	1.5
Dowfume E	More than 3	2	2
Dowfume P	More than 2.5	2	More than 2
Methylene chloride mix	More than 2	2	1.5

* The composition of the various Dowfume mixtures is listed below.

Dowfume 75 = Ethylene dichloride 75%, carbon tetrachloride 25%
Dowfume Br-10 = 10% methyl bromide added to 3-1 mixture of ethylene dichloride and carbon tetrachloride
Dowfume Br-10-S = 10% methyl bromide added to 3-1 mixture of propylene dichloride and carbon tetrachloride
Dowfume C = 10% methyl bromide + 90% carbon tetrachloride
Dowfume E = 10% methyl bromide + 90% ethylene dichloride
Dowfume P = 10% methyl bromide + 90% propylene dichloride
Methylene chloride mix = 10% methyl bromide + 90% methylene chloride.

WHEAT STORAGE

Condition of Wheat in Steel Bins at Experimental Storage Sites*

At Hutchinson, the regular quarterly sampling was completed early in July, and that at Jamestown, North Dakota, was done during August. As a result of these samplings, the insect populations were shown to be at the lowest point observed since the bins were filled in July, 1941.

It now appears that the insect problem at the Jamestown, North Dakota, site is practically negligible, inasmuch as the wheat has now been in storage for more than a year and no insect infestations of any consequence have developed. At the Hutchinson, Kansas, storage site, however, the situation is now in sharp contrast to that existing at Jamestown. Although infestations in June were low at both storage sites, sharp increases in insect populations were noted in the bins at Hutchinson during July and August, while at Jamestown the population remained static.

By the middle of August, 37 of the 1000-bushel bins at Hutchinson showed a dangerous rise in temperature. Samples taken from these bins showed 34 to be infested with insects, and 26 of them graded "weevily". The maximum population observed was 61 insects per 1000 grams, the average for the infested bins being 11 insects per 1000 grams. Fumigation of the infested bins stopped the heating of the grain before damaging temperatures were reached.

Simultaneously with the above condition in 1000-bushel bins, three 2740-bushel bins in another part of the bin-site indicated an abnormal condition. These bins were located adjacent to a bin into which grain was run after the cleaning process. It is believed that a large number of insects escaped during the cleaning process and migrated into the three near-by bins, thus establishing dangerous populations.

With the exception of one 5,000-bushel bin and the three bins noted above, no intense insect population developed in bins of 2740-bushel capacity or larger. In the case of the one 5,000-bushel bin, a small leak in the manhole cover permitted water to enter, causing a small aamount of surface grain to go out of condition near the center. Large numbers of flat grain beetles were attracted to this musty grain, which served as a center of dispersal. A representative sample from the spoiled grain contained 251 insects per 1000 grams, while the infestation in the grain mass averaged 18 insects per 1000 grams. The flat grain beetle was the most abundant species observed in the samples taken from the infested bins.

---

* Reported by H. H. Walkden and R. B. Schwitzgebel in cooperation with the Bureau of Agricultural Chemistry and Engineering.

From the foregoing observations, it appears that, from the standpoint of insect infestation, the larger-capacity bins develop dangerous insect populations more slowly than bins of the 1000-bushel size. This condition is explained at least in part by the fact that the average temperature of the larger-capacity bins is several degrees lower than that in the 1000-bushel bins. A comparison of the average temperatures in several types of bins is given in table 12.

Table 12: -- Average bin temperatures, Hutchinson, Kansas, June 1 to September 15, 1942.

Bin description	June 1	June 15	July 1	July 15	Aug. 1	Aug. 15	Sept. 1	Sept. 15
1000-bushel	64	73	75	77	80	82	82	76
1000-bushel (painted white)	57	61	64	69	68	73	77	73
2740-bushel	58	60	66	71	75	77	76	74
5,000-bushel (painted white)	54	57	62	--	69	69	72	71
5,000-bushel	59	61	65	70	72	74	75	75

1. Bins which are painted white showed the lowest average temperatures throughout the period.

2. The rise in average bin temperature was more rapid in unpainted 1000-bushel bins, reaching 80° F. by August 1. Thus, much of the grain in such bins was warmer than the average for the bin, permitting rapid reproduction of the insects.

Thus, after a storage period of one year, it appears that at Jamestown, North Dakota, insect infestation is practically negligible as a hazard in safe storage, while at Hutchinson, Kansas, it is an important factor in limiting the safe storage period.

Distribution of the Insect Populations within Bins

As reported previously, a study was made during the winter months to determine the winter pattern of infestation in bins at Hutchinson, Kansas. As a result of this study, it was found that during the cold months insect populations were concentrated near the center of the grain mass, or in the south quadrant of the bin.

During August, a similar study was conducted, and the results are summarized in table 13. It was found that at that period of the year, which is the period of highest bin temperatures, no great concentration of insect populations existed. It may be seen in table 13 that the largest numbers of insects were found in the upper half of the bin and also that larger numbers of them were located in the south and west quadrants of the bins, extending into the center, in both the upper and lower portions of the bins. It is quite probable that such a distribution is a result of a definite response to temperature, inasmuch as the upper south and west portions of the grain are the first to show a rise in temperature in the spring and attain higher temperatures during the summer months than the north and east portions of the grain.

Table 13:--Distribution of insects in 1000-bushel bins, Hutchinson, Kansas, August, 1942.

	Location in bins; number of insects in 200-gm. (cir.) samples									
	Upper half					Lower half				
Bin	Center	North	East	South	West	Center	North	East	South	West
2-11	26	8	14	7	32	67	4	16	10	5
1-10	18	5	3	102	12	6	1	2	1	3
2-6	20	11	14	15	43	31	7	8	11	13
3-8	10	10	16	39	27	15	5	16	8	17
2-5	84	17	24	186	61	67	13	10	101	62
Totals	158	51	71	349	175	186	30	52	131	100
Averages	31.6	10.2	14.2	69.8	35.0	37.2	6.0	10.4	26.2	20.0

Migration of Insects as Revealed by Collections from Insect Traps

At Hutchinson, a considerable amount of work has been done during the quarter to determine the extent of stored grain insect migration occurring on the bin site, and into the bins. Three methods were employed in this study: (1) tanglefoot screens along the boundary lines, (2) bin ventilator traps, and (3) a revolving trap.

Results with tanglefoot screens

Four screens, each 3 feet square, were mounted on 2" x 4" supports, and were elevated 4 feet above the ground level. One screen was placed on each side of the bin site. The screens were coated with tanglefoot to catch and hold any insects flying into them. The traps were put into operation the first week in July, and as the stored grain insects were removed at frequent intervals during the following three weeks, their numbers and kinds were recorded. The results are given in table 14. It may be noted that the greatest number of stored grain insects were taken on the screens away from the bins, and also that more insects were taken on the north and west sides of the bin site than on the south and east boundaries. It is of interest to note here that a grain elevator is located about $\frac{1}{4}$ mile east of the site and it was expected that more insects would be taken on that side. The fact that the largest numbers of insects were taken on the north screen indicates that migration was with the wind, since the prevailing wind is from the south.

Table 14:--Numbers of stored grain insects taken on tanglefoot screens, Hutchinson, Kansas, July, 1942.

Screen location	Numbers of insects collected from screen: Flat grain beetle	Foreign grain beetle	Hairy fungus beetle	Others	Total
	Insects taken on side away from bins				
South	54	8	54		116
West	64	10	36	1 lesser grain borer 2 rice weevil	
North	140	22	152		314
East	5	6	28		39
Total	263	46	270	3	582
	Insects taken on side facing bins				
South	52	8	31		91
West	9	4	15		28
North	5	-	19		24
East	2	5	15		22
Total	68	17	80		165
Total taken	331	63	350	3	747

Results with bin ventilator traps

Two bins which have been tightly caulked so that the only means by which insects can gain entrance is through the ventilator, have been fitted with ventilator traps to retain any insects entering in this manner. These traps have been in operation continuously since April 17. It was noted in the report for the previous quarter that up to July 1 no large migration of stored grain insects had occurred. Since that time, large numbers of such insects have been taken in these traps. The weekly totals of the various species are given in table 15. The following points in connection with this phase of the work are of interest: (1) the flat grain beetle was taken in greatest abundance; (2) the lesser grain borer ranks third in number taken, and is one of the most destructive of the grain pests in the region; (3) the period of greatest migration occurred during August and the first week of September. This point is of importance because of its bearing on the re-infestation of bins fumigated during the migration period.

Table 15:--Weekly catches of stored grain insects in bin ventilator traps, Hutchinson, Kansas, July 1 to September 22, 1942. (Totals from two traps operated continuously.)

Period	Flat grain beetle	Foreign grain beetle	Lesser grain borer	Hairy fungus beetle	Rice weevil	Red flour beetle	Total	Booklice (approximate)
July 1-7	35		1	1	5		42	500
July 8-14	104	8	1	1		2	116	450
July 15-21	17						17	300
July 22-28	57	33	9	8		1	108	1000
July 29-Aug. 4	75	21	2		1		99	1200
Aug. 5-11	207	48	1	6	1		263	3100
Aug. 12-18	116	39		15			170	4500
Aug. 19-25	133	30		17			180	4300
Aug. 26-Sept. 1	120	11		20			151	6000
Sept. 2-8	149	74	53	39			315	2600
Sept. 9-15	46	28	21	16			111	3600
Sept. 16-22	76	4	14	2			96	4000
Totals	1135	296	102	125	7	3	1668	31550

Results with a revolving insect trap

This trap consists essentially of two nets revolving through the air on six-foot arms, powered by an electric motor. The nets revolve at an approximate speed of 50 R.P.M., one at 3 feet above ground and the other at a six-foot level. It was originally planned to operate this trap continuously but press of other work prevented. It was, however, run for varying periods, and observations were made on flights both during the daytime and nighttime hours.

In the hotter periods of the summer, very little insect migration occurred during the day, but during such periods, migrations were noted late in the day from 6 P. M. until dusk. By far the greatest number of stored grain insects were taken in that period, although some migration continued throughout the night.

In periods of more moderate weather, migrations were observed to occur during the cooler parts of the daytime hours. The average insect catch during the period 7:00 A. M. to 5:00 P. M. was 2.0, the maximum being 7 and the minimum 0.2 insects per hour. During the period 5:00 P. M. to 7:00 A. M. the average catch was 43 insects per hour, with a maximum of 95 and a minimum of 6.

The maximum hourly daytime catch was recorded during the period September 14-20, while the maximum hourly nighttime catch occurred during the period August 31 to September 6.

A summary of the weekly catches of the various species, together with the number of hours of operation for each period, is presented in table 16. The hairy fungus beetle was taken in greatest numbers, with the foreign grain beetle and the flat grain beetle ranking second and third, respectively.

Results obtained with the three types of traps show that there was a very definite migration of stored grain insects from early in July to the first week in September. As noted earlier in this report, it was during this same period that insect troubles began to appear in many of the bins at the Hutchinson site.

Table 16:--Weekly totals of species of stored grain insects caught in revolving trap. Hutchinson, Kans. July 1 to Sept. 22, 1942.

Period	Total number of insects caught							Hours operated
	Flat grain beetle	Foreign grain beetle	Hairy fungus beetle	Lesser grain borer	Rice weevil	Red flour beetle	Total	
July 1-7	44	19	15		1		79	33
July 8-14	301	130	1622	5	1	3	2062	76
July 15-21	263	70	562	2		1	898	38
July 22-28	174	390	347	4	3		918	38
July 29-Aug. 4	356	320	658	15	1	1	1351	53
August 5-11	200	823	883	1			1907	22
August 12-18	203	251	976	1	1		1432	38
August 19-25		Not operated						
Aug.26-Sept. 1	6	2		3	1		12	8
Sept. 2-8	414	674	212	37	1		1338	15
Sept. 9-15	115	30	91	95			331	61
Sept. 16-22	14			93			107	9
Totals	2090	2709	5366	256	9	5	10435	

Covered Bins

In August, 1941, one bin was fitted with a Kraft paper cover treated with nicotine sulfate. Observations in September, 1942, showed that large numbers of flat grain beetles and sawtooth grain beetles were dead on the surface of the treated paper, some areas having more than 500 insects per square foot. This method of protecting the surface, while appearing to be quite effective, has the great disadvantage of high cost per bin, and for that reason is not considered a practical method.

In November, 1941, the surface of the grain in two bins was covered with cotton batting, one cover being sprayed with oil. During periods of migration, insects were observed to be crawling through the un-oiled cotton into the wheat below. This bin developed abnormally high temperatures during the latter part of September, indicating a heavy insect infestation. It is planned to remove the cotton and determine the condition of the grain.

In the case of the bin covered with the oiled cotton bat, large numbers of insects were killed on the surface oil, but by September the oil had been absorbed by the cotton so that its effectiveness was limited.

Altogether, covers on grain surfaces have been unsatisfactory. Their cost is high, they are difficult to apply, and their presence makes sampling difficult.

Condition of Wheat Stored in C. C. C. Steel Bins in Reno County, Kansas

A number of bins in Reno County in the vicinity of Hutchinson, Kansas, were sampled to determine the insect infestation within two months after they had been filled with 1941 wheat from the farm, country elevators, and terminal storage. At the time of filling the bins, this wheat was accepted as insect free. Of the 18 bins sampled 13 graded weevily and all were infested, as shown in table 17.

Table 16:--Weekly totals of species of stored grain insects caught in revolving trap. Hutchinson, Kans. July 1 to Sept. 22, 1942.

Period	Total number of insects caught							Hours operated
	Flat grain beetle	Foreign grain beetle	Hairy fungus beetle	Lesser grain borer	Rice weevil	Red flour beetle	Total	
July 1-7	44	19	15		1		79	33
July 8-14	301	130	1622	5	1	3	2062	76
July 15-21	263	70	562	2		1	898	38
July 22-28	174	390	347	4	3		918	38
July 29-Aug. 4	356	320	658	15	1	1	1351	53
August 5-11	200	823	883	1			1907	22
August 12-18	203	251	976	1	1		1432	38
August 19-25	Not operated							
Aug.26-Sept. 1	6	2		3	1		12	8
Sept. 2-8	414	674	212	37	1		1338	15
Sept. 9-15	115	30	91	95			331	61
Sept. 16-22	14			93			107	9
Totals	2090	2709	5366	256	9	5	10435	

Covered Bins

In August, 1941, one bin was fitted with a Kraft paper cover treated with nicotine sulfate. Observations in September, 1942, showed that large numbers of flat grain beetles and sawtooth grain beetles were dead on the surface of the treated paper, some areas having more than 500 insects per square foot. This method of protecting the surface, while appearing to be quite effective, has the great disadvantage of high cost per bin, and for that reason is not considered a practical method.

In November, 1941, the surface of the grain in two bins was covered with cotton batting, one cover being sprayed with oil. During periods of migration, insects were observed to be crawling through the un-oiled cotton into the wheat below. This bin developed abnormally high temperatures during the latter part of September, indicating a heavy insect infestation. It is planned to remove the cotton and determine the condition of the grain.

In the case of the bin covered with the oiled cotton bat, large numbers of insects were killed on the surface oil, but by September the oil had been absorbed by the cotton so that its effectiveness was limited.

Altogether, covers on grain surfaces have been unsatisfactory. Their cost is high, they are difficult to apply, and their presence makes sampling difficult.

Condition of Wheat Stored in C. C. C. Steel Bins in Reno County, Kansas

A number of bins in Reno County in the vicinity of Hutchinson, Kansas, were sampled to determine the insect infestation within two months after they had been filled with 1941 wheat from the farm, country elevators, and terminal storage. At the time of filling the bins, this wheat was accepted as insect free. Of the 18 bins sampled 13 graded weevily and all were infested, as shown in table 17.

Table 17:--Insect infestation in C. C. C. bins in Reno County, Kansas, August, 1942.

Bin No.	Bin capacity (bu.)	Flat grain beetle	Sawtooth grain beetle	Lesser grain borer	Rice weevil	Granary weevil	Cadelle	Others
		Average number of insects per quart						
101	2740	6						1 red flour beetle
102	2740	2	1					
103	2740	4						
104	2740							1 hairy fungus beetle
106	2740	27				1		1 red flour beetle
107	2000	9	1					
301	2000	1						
302	2000	3	1		1			1 mealworm
304	2000	12	3	16	1			1 red flour beetle
305	2000	1	1					
306	2000	1				3		
307	2000	5	1	1	6			
308	2000	3	1		4		1	
309	2000	7	1		16			
310	2000	2	7		22			1 hairy fungus beetle
311	2000		5		6		1	
312	2000	28			1		1	1 foreign grain beetle
313	2000	23			1		1	3 red flour beetle

Experimental Fumigation Studies

Experimental fumigations of wheat with some 12 different mixtures have been conducted and are reported in table 18.

Table 18:--Summary of results obtained in experimental fumigations of wheat, Hutchinson, Kansas, June to September, 1942.

Bin No.	Bushel capacity	Date treated	Dosage per 1000 bu.	Amount used	Kill (%)	Germination (%) Before	After
			Dowfume 75				
1-3	1000	6-11	4 gals.	4 gals.	84	92	91
2-12	1000	9-30	4 "	4 "	80		
3-12	1000	9-30	4 "	4 "	99.7		
1-16	1000	6-11	5 "	5 "	87	92	89
9-13	1000	6-11	6 "	6 "	98	92	92
3-17	1250	6-30	4 "	5 "	93	69	69
310	2000	9-16	3 "	6 "	81	79	
309	2000	9-16	4 "	8 "	91	86	
308	2000	9-16	5 "	10 "	100	84	
9-1	2740	9-30	4 "	11 "	100		
9-11	2740	6-10	4 "	11 "	98	92	93
10-1	2740	9-30	4 "	11 "	94		
10-2	2740	9-30	4 "	11 "	100		
9-12	2740	6-10	5 "	14 "	90	86	89
10-11	2740	6-10	6 "	16.5 "	98	50	56
(The floor and walls are caulked in the above bins.)							
No caulking (except by contractors' mistake, some of the wall joints are caulked)							
9-10	2740	6-10	6 gals.	16.5 gals	100	88	90
Floor caulked only							
10-10	2740	6-10	6 "	16.5 "	96	86	84
Floor, walls and roof caulked							
10-12	1000	6-30	3 "	3 "	71	8	10
10-9	2740	6-30	3 "	8 "	73	85	92
Subminimal dosage in plain bin (floor and walls caulked)							
11-11	2740	6-26	3 "	8 "	70	45*	
			Dowfume Br-10				
1-2	1000	6-16	1.5 gals.	1.5 gals.	98	85	81
2-16	1000	6-16	1.5 "	1.5 "	100	90	61
2-12	1000	6-16	2 "	2 "	86	79	
3-12	1000	6-16	2 "	2 "	95	82	
9-1	2740	6-16	2 "	5.5 "	100	73	61
10-2	2740	6-16	2 "	5.5 "	99	80	61
11-9	2740	6-16	1.5 "	4 "	100	79	29
11-11	2740	6-16	1.5 "	4 "	93	70	45
10-1	2740	6-16	2.5 "	7 "	100	45	19
(The floors and walls are caulked in the above bins.)							

(Table continued)

* This bin was fumigated with Dowfume 75 two weeks after being treated with Dowfume Br-10. The latter fumigant may have been still affecting the germination of the grain, which might account for the low germination.

Table 18 continued

Bin No.	Bushel capacity	Date treated	Dosage per 1000 bu.	Amount used	Kill (%)	Germination (%) Before	After
Perforated walls and floor							
2-1	1000	7-23	2 gals.	2 gals.	54	88	88
Floor and walls caulked							
4-15	1250	7-13	2 "	2.25 "	68	83	79
9-8	1650	7-13	2 "	3.25 "	99	25*	39
10-8	2150	7-13	2 "	4.25 "	99	42*	62
Cooling tube, solid							
9-2	2740	6-19	2 "	5.5 "	100	78	56
10-3	2740	6-19	2 "	5.5 "	100	67	43
Cooling tube, perforated							
9-3	2740	6-19	2 "	5.5 "	100	78	68
11-1	2740	6-19	2 "	5.5 "	80	62	49
Floor and walls caulked - Sorghum							
½-14	1000	8-18	2 "	2 "	50	51	39
			Dowfume Br-10-S				
1-2	1000	7-6	2 gals.	2 gals.	100	81	76
2-16	1000	7-6	2 "	2 "	100	61	84
11-9	2740	7-6	2 "	5.5 "	100	29	59
11-11	2740	7-6	2 "	5.5 "	100	45	72
8-12	1000	8-3	1 "	1 "	70	-	27
12-9	2740	8-3	1.5 "	4 "	100	-	28
103	2740	9-2	1.5 "	4 "	98	89	-
107	2000	9-2	1.5 "	3 "	74	89	-
1-2	1000	9-14	2 "	2 "	92	76	65
1-3	1000	9-14	2 "	2 "	74	35	79
1-4	1000	9-14	1.5 "	1.5 "	50	91	82
1-5	1000	9-14	1.5 "	1.5 "	42	91	84
3-9	1000	10-2	4 "	4 "	99.5		
4-8	1000	10-2	5 "	5 "	100		
2-5	1000	10-2	6 "	6 "	100		
			Dowfume E				
1-16	1000	8-3	2 gals.	2 gals.	80	89	84
11-11	2740	8-3	2 "	5.5 "	100	72	43 also 55
3-6	1000	9-11	3 "	3 "	78	91	84
3-7	1000	9-11	2.5 "	2.5 "	57	89	82
			Ethide				
1-10	1000	8-27	2 lbs.	2 lbs.	70	91	83
1-11	1000	8-27	2 "	2 "	99	87	86
1-12	1000	8-27	3 "	3 "	81	87	79
1-13	1000	8-27	3 "	3 "	99	90	83

Table continued

* BPI tests for these bins April 1, 1942 - 9-8, 44%; 10-8, 75%.

Table 18 continued

Bin No.	Bushel capacity	Date treated	Dosage per 1000 bu.	Amount used	Kill (%)	Germination (%) Before	After
			Dowfume P				
9-13	1000	8-3	2 gals.	2 gals.	76	92	79
11-9	2740	8-3	2 "	5.5 "	100	59	86
104	2740	9-2	2 "	5.5 "	92	97	
106	2740	9-2	1.5 "	4 "	70	81	
1-6	1000	8-31	2 "	2 "	82	84	81
1-7	1000	8-31	2 "	2 "	81	77	81
1-8	1000	8-31	2.5 "	2.5 "	77	83	83
1-9	1000	8-31	2.5 "	2.5 "	81	84	86
			Methylene Chloride Mixture				
8-12	1000	6-19	2 gals.	2 gals.	91	68	29
12-9	2740	6-19	2 "	5.5 "	98	55	38
8-12	1000	6-30	1.5 "	1.5 "	88	29	-
12-9	2740	6-30	1.5 "	1.5 "	99	38	-
101	2740	9-2	1.5 "	4 "	98	90	
102	2740	9-2	1.5 "	4 "	100	94	
2-10	1000	9-14	2 "	2 "	83	93	83
2-11	1000	9-14	2 "	2 "	82	87	82
			Dowfume C				
1-3	1000	8-3	2 "	2 "	100	93	80
9-11	2740	8-3	2 "	5.5 "	100	91	82
3-4	1000	9-11	2 "	2 "	88	93	82
3-5	1000	9-11	2 "	2 "	75	92	85
7-1	2740	9-14	1.5 "	4 "	100	70	52
12-9	2740	9-14	1.5 "	4 "	100	28	22
			Allyl Bromide				
2-4	1000	8-27	mix #1*	2 gals.	95	86	81
2-5	1000	8-27	mix #2*	2 "	93	49	48
2-6	1000	8-27	mix #3*	2 "	98	86	81
4-7	1000	10-1	mix #4*	2 "	100		

(Table continued)

* Mix 1 = 420 grams allyl bromide in 2 gallons carbon tetrachloride.
Mix 2 = 630 " " " " 2 " " "
Mix 3 = 840 " " " " 2 " " "
Mix 4 = 978 " " " " 2 " " "

Table 18 continued

Bin No.	Bushel capacity	Date treated	Dosage per 1000 bu.	Amount used	Kill (%)	Germination (%) Before	After
			Pronto*				
1-9	1000	9-23	3 gals.	3 gals.	74		
1-10	1000	9-23	3 "	3 "	31		
2-7	1000	8-31	3 "	3 "	98	86	
4-8	1000	9-10	1 "	1 "	75	81	
1-13	1000	9-23	4 "	4 "	57		
			F-1 Acrylonitrile				
				Mixture with CCl_4			
½-1	1000	7-16	2 gals.	1-4.3	99	91	91
		The above bin is built of concrete blocks.					
Floor and walls caulked							
1-5	1000	7-16	2 gals.	1-7	100	82	91
10-7	2150	7-16	2 "	1-15	100	30	34
			F-28 Trichloroacetonitrile				
Floor, walls, and roof caulked							
1-1	1000	7-16	2 gals.	1-20	75	78	83
Floor and walls caulked							
1-4	1000	7-16	2 "	1-15	94	83	91
9-9	1650	7-16	2 "	1-7	82	46	52

* Pronto = 3 - 1 mixture of ethylene dichloride - carbon tetrachloride saturated with SO_2.

Effect on germination of the various fumigants

The effect on germination of the several fumigants used in the experimental series has been made the subject of a special study. There is some evidence to show that mixtures containing methyl bromide have a deleterious effect on the germination of wheat. Further work to establish this point more definitely is being conducted in both wheat and corn, and the results will be included in a later report.

Retention of fumigants in fumigated grain

Check probes were placed in each of the bins at the time of fumigation. These were removed 72 hours after fumigation, and a fresh set of probes inserted in the grain at that time. These were allowed to remain in the grain for a period of one week, when they were removed and the mortality noted. Fresh check probes were put into the bins at weekly intervals until no further kill was obtained. In this manner, the length of time that killing concentrations of fumigant were retained in the bins was determined.

In wheat, it was found that killing concentrations of Dowfume 75 remained in the bins from 9 to 10 weeks in 1000-bushel bins and from 12 to 14 weeks in 2740-bushel bins. This long period of retention is of great importance, since the effective period of the fumigant is greatly extended, and thus no doubt inhibits re-infestation of the grain.

Observations are now being made in corn to determine the retention period for Dowfume 75.

The Dow mixtures containing methyl bromide did not persist in wheat for so long a time, the period ranging from two to four weeks. Observations on the retention of these fumigants in corn, however, showed that killing concentrations were retained for less than one week. It is possible that the greater oil content of corn permits more rapid absorption than is the case in wheat, or the larger air spaces between the kernels facilitates the escape of the gas.

Experimental fumigation at Jamestown, North Dakota

During August, two bins constructed of Tempered Presdwood were fumigated experimentally with Dowfume Br-10, the bins being of 700- and 1100-bushel capacity. Each has walls 4 feet high, with diameters of 14 and 18 feet, respectively. The grain is heaped in the centers to a depth of 7 feet, and the surface covered with two thicknesses of Sisalkraft paper. A dosage of 2 gallons per 1000 bushels was applied at the top of the cone in the center of the bin. Check boxes containing live insects were placed in various parts of the bins to determine the lateral diffusion of the fumigant.

On examination of the check boxes, it was found that a kill of 83% was obtained in the 700-bushel bin and a kill of 91% in the 1100-bushel bin. However, kills in the surface check boxes were very low, indicating that while the fumigant diffused laterally in the lower portion of the grain, no killing concentrations were obtained near the surface, even in the center of the bin surface where the fumigant was applied. Thus in this type of bin it is not feasible to apply all of the fumigant on the center of the bin surface, since by this method surface infestations escape.

Fumigation of wood bins

One 2700-bushel bin constructed of planks was fumigated with a dosage of 2 gallons of Dowfume Br-10, the standard dosage for steel bins. This bin is 15 feet square, with about 14 feet of grain. Check boxes were placed in the grain before fumigation, and left in the grain for 72 hours after the fumigant was applied. A kill of only 42 percent was obtained in this bin, and this was almost entirely confined to the top two feet of grain--the insects in the capsules placed at lower levels survived.

Fumigation of three 2740-bushel steel bins at the same time and dosage gave 100% kills. Apparently the loose construction of these plank bins permits rapid escape of the gas so that killing concentrations are not obtained. It will no doubt require a much heavier dosage to fumigate such bins successfully. Further work with various types of wooden bins is in progress in order to establish proper dosages for such bins.

Insect Infestation in Grain Sorghum

About 8,000 bushels of grain sorghum are being stored experimentally at the Hutchinson bin site. This sorghum was put into the bins early in the spring, and most of it has a moisture content of from 12.5 to 13.5 percent, this figure being 2 to 4 percent higher than that of the wheat being stored at the same site. Preliminary samplings at the time the sorghum was put into the bins indicated that only a small insect population was present. However, during August, a majority of the bins containing sorghum began heating as a result of greatly increased insect infestation, and all of them graded "weevily". The infestation in all of the nine bins was of about the same intensity, averaging about 13 insects per 1000 grams of grain. These bins were fumigated with Dowfume Br-10 at a dosage of 2 gallons per 1000 bushels, and in all but one the heating was arrested, even though samples taken after fumigation showed that only a slight reduction in insect population had been effected by the treatment.

The sorghum in one bin continued to heat after fumigation, and it was decided to move half of the grain into another bin and treat each lot with a double dosage of fumigant. This treatment was applied and heating was stopped, and a substantial reduction in insect population was accomplished.

Apparently the normal dosage of fumigant for wheat is not sufficient for grain sorghum, and further work is now in progress to determine the required dosage.

Fumigation experiments with sorghum

The fumigation of sorghum seed presents certain problems that have not as yet been solved. A few tests have been conducted with Dowfume 75 and Dowfume Br-10, but the dosages satisfactory for wheat do not give a good kill in sorghum. This may be due in part to the difference in shape and size of the sorghum seed and in part to the dockage in the seed. Results obtained to date are tabulated below.

Table 19:--Fumigation experiments with sorghum seed.

Bin No.	Bushel capacity	Date treated	Dosage per 1000 bu.	Percent kill	Fumigant
½-14	1000	9/22/42	6 gals.	85	Dowfume 75
½-15	1000	9/22/42	6 "	50	" 75
½-4	1000	9/22/42	3 gals.	25	Dowfume Br-10
½-5	1000	9/22/42	3 "	54	" Br-10

Effect of Grain Moisture on the Development of Stored Grain Insects*

As these studies progress, some interesting facts become evident with regard to the variation in the moisture requirements of different species of stored grain insects. Previous reports have shown that there is a definite temperature and moisture relationship, of apparently very limited range, in which some species will feed and reproduce. This fact is more pronounced in the species which live at least during their larval stages, within the wheat berry. With some species commonly classed as "bran bugs", i. e., the confused flour beetle, the rust red flour beetle, and the sawtoothed grain beetle, another factor has been noticed. It has been observed from time to time that, regardless of existing conditions, a considerable period of time elapses before the larvae of these species appear. The adults seem to feed and survive normally, but not until enough flour has been milled by the feeding of adults, to support the young larvae, do the latter seem to be able to complete their development. The young larvae are apparently unable to feed successfully upon the whole or cracked wheat berry. It was at first believed that the adults would not oviposit in grain of the lower moisture contents. This theory has been exploded by the discovery that adult flour beetles will reproduce in flour with a moisture content as low as 8 percent. This observation is further corroborated by the fact that after extended periods of time an occasional larva will complete its development in wheat. No doubt many eggs are laid, but the lack of suitable food for the newly hatched larvae prevented their development in dry wheat. In future studies, therefore, the factor of dockage will be considered with relation to the possibility of development of "bran bugs" in wheats of different moisture content.

During the past quarter three sets of tests have been in progress. Two sets each with moisture variants of 9, 10, and 11%, one of which was held at a constant temperature of 80° F. and the other at 85° F. The third set was held at a constant temperature of 90° F. with moisture content variants of 7, 8, and 9%. The results of bi-weekly examination of these tests are summarized in tables 20-22.

These tests again show that at a given temperature, the survival of adults of the various species varies with the moisture content of the grain. That is, the higher the moisture content of the wheat, the higher is the percentage of survival of adults.

Very little significant difference with most of the species is noted between those confined in wheat of the same moisture at 80° F. or 85° F.

---

* Reported by R. T. Cotton and J. C. Frankenfeld

Of the six species included in these tests, only the granary weevil had reproduced at the end of 15 weeks exposure in the 85° F. tests. Reproduction by this species occurred in all three moisture variant wheats, by the end of the seventh week. At the 80° F. temperature only the granary weevil reproduced in 9 and 10% moisture wheat. In the 11% moisture wheat series, the granary and rice weevil reproduced. At this temperature the evidence of reproduction by the granary weevil in 9% wheat was delayed as compared with the 10 and 11% wheat. At the end of the seventh week, adult progeny were recovered from the 10 and 11% wheats, but it was not until the end of the 9th week that such recovery was made in the 9% wheat.

Owing to the tremendous amount of work involved, the actual number of progeny produced has not been recorded. Although we recognize the additional value which could be derived from such data, our chief interests have been to determine the effect of moisture and temperature on the survival and ability to reproduce of these different species. However, in the course of the bi-weekly observations great differences in the rate of reproduction are discernable. In general, with the granary weevil reproduction was light at temperatures below 80° F., in wheats with a moisture content up to 11%. However, at 80 and 85° F. reproduction was greatly accelerated, and was progressively greater as the moisture content was increased. The optimum temperature for the development of the granary weevil appears to be between 80 and 85° F. The number of progeny was greater in the 11% wheat at 80° F. than in any of the other moisture variants at either 80 or 85° F.

The rice weevil apparently does not reproduce in wheat with a moisture content of 10% or less at temperatures up to 85° F. or reproduction is so retarded that no evidence of it has been seen to date.

That very definite limits of optimum temperature and moisture are required by the various species, and that these vary considerably with different species is further emphasized in the data of the lesser grain borer. No reproduction by this species has been observed in wheat with moisture content up to 11% at temperatures ranging from 65 to 85° F. It has been observed that a higher percentage of survival of this species occurs in the wheat with a 9% moisture content than in wheat with 10 or 11% moisture, at temperatures up to 85° F. Oviposition by this species may occur in 9, 10, or 11% moisture wheat, but the eggs either do not hatch, or the young larvae are not able to penetrate the epidermis of the wheat berry, or survive on the grain dust that is available for food.

As previously reported, all six species included in the tests reproduced freely in 10 and 11% moisture wheat, at 90° F. by the end of the 8th week. Subsequent examinations showed that all six reproduced in 9% wheat at this temperature also. This series of tests was then discontinued, and a new series was begun using 7, 8, and 9% moisture wheat, at a constant temperature of 90° F. Table 22 summarizes the results of the weekly examinations of this series. By the end of the first week, the granary and rice weevil had all succumbed in 7% wheat. At the end of six weeks, all the lesser grain borers, the sawtoothed grain beetles and the rust red flour beetles had died. Only the confused flour beetle was able to maintain a fairly high percentage of survival at 90° F. in 7% moisture wheat. No reproduction of any species was observed at the end of seven weeks.

In 8% wheat the percentage of survival of the granary weevil was reduced to 10% after one week, all were dead at the end of four weeks. All of the rice weevils died within a period of two weeks. The low percentage of survival of the confused flour beetle was undoubtedly due to other conditions than the factors of temperature and moisture. The greatly increased percentage of survival of the lesser grain borer in 8% wheat as compared to 7% wheat indicates the approach to conditions more suitable for the development of this species. The sawtoothed grain beetle and the rust red flour beetle show only a slightly higher percentage of survival in 8% than in 7% wheat. No reproduction of any species was observed.

In 9% moisture wheat all species show a marked increase in the percentage of survival over the 7 and 8% wheat. At the end of six weeks, adult progeny of the lesser grain borer were recovered. No reproduction had been observed with any of the other species at the end of seven weeks.

Reference to the report of these tests in the Report for the period April to June, 1942, will show that progeny were recovered from the sawtoothed grain beetle and the rust red flour beetle in 9% wheat at a constant temperature of 90° F. These progeny were recovered after four weeks exposure, and it was noted that there was a cessation of reproduction in subsequent examinations. It is probable that reproduction by these two species in 9% wheat at 90° F. is rare and not likely to be extensive at any time.

Table 20: -- Survival of various species of stored grain insects reared in 9, 10, and 11% moisture wheat at 80° F.

Species of Insect	Percentage of survival after							
	1 Week	3 Weeks	5 Weeks	7 Weeks	9 Weeks	11 Weeks	13 Weeks	15 Weeks
9% Wheat								
Granary weevil	100	92	85	37	11*			
Rice weevil	46	23	18	3	0			
Confused flour beetle	98	93	84	71	44	36	30	25
Lesser grain borer	95	89	88	85	85	84	83	77
Sawtoothed grain beetle	95	71	46	23	11	2	0	
Rust red flour beetle	81	41	17	9	0			
10% Wheat								
Granary weevil	97	92	90	88*				
Rice weevil	100	88	15	4	3	2	0	
Confused flour beetle	98	96	85	77	68	52	42	36
Lesser grain borer	99	97	63	59	58	51	44	41
Sawtoothed grain beetle	100	85	60	40	19	10	5	3
Rust red flour beetle	90	58	20	8	2	0		
11% Wheat								
Granary weevil	99	97	96	96*				
Rice weevil	98	92	24	2	0*			
Confused flour beetle	100	100	95	87	78	72	62	51
Lesser grain borer	100	100	30	2	2	0		
Sawtoothed grain beetle	99	93	67	36	25	20	12	2
Rust red flour beetle	95	81	48	23	11	7	4	0

* Adult progeny recovered.

Table 21: -- Survival of various species of stored grain insects reared in 9, 10, and 11% moisture wheat at 85° F.

Species of Insect	Percentage of survival after 1 Week	3 Weeks	5 Weeks	7 Weeks	9 Weeks	11 Weeks	13 Weeks	15 Weeks
9% Wheat								
Granary weevil	96	95	94	58*				
Rice weevil	72	52	19	0				
Confused flour beetle	99	77	31	20	17	17	12	2
Lesser grain borer	100	100	98	70	67	63	58	50
Sawtoothed grain beetle	84	54	22	7	1	0		
Rust red flour beetle	71	34	14	11	4	0		
10% Wheat								
Granary weevil	97	94	88	78*				
Rice weevil	74	63	2	0				
Confused flour beetle	97	82	42	20	14	14	14	10
Lesser grain borer	100	100	80	73	68	61	56	51
Sawtoothed grain beetle	100	66	27	12	10	1	0	
Rust red flour beetle	81	41	15	6	5	0		
11% Wheat								
Granary weevil	100	96	93	91*				
Rice weevil	95	83	15	4	0			
Confused flour beetle	100	97	95	82	74	73	70	62
Lesser grain borer	99	95	16	6	5	5	5	5
Sawtoothed grain beetle	97	82	35	11	7	2	0	
Rust red flour beetle	90	76	35	19	8	5	3	0

* Adult progeny recovered.

Table 22: -- Survival of various species of stored grain insects reared in 7, 8, and 9% moisture wheat at 90° F.

Species of Insect	Percentage of survival after						
	1 Week	2 Weeks	3 Weeks	4 Weeks	5 Weeks	6 Weeks	7 Weeks
<u>7% Wheat</u>							
Granary weevil	0	0	0	0	0	0	0
Rice weevil	0	0	0	0	0	0	0
Confused flour beetle	99	92	88	84	71	66	53
Lesser grain borer	62	36	21	5	2	0	0
Sawtoothed grain beetle	79	36	19	6	3	0	0
Rust red flour beetle	72	44	34	18	7	1	0
<u>8% Wheat</u>							
Granary weevil	10	6	5	1	0	0	0
Rice weevil	1	0	0	0	0	0	0
Confused flour beetle	95	93	86	65	38	27	17
Lesser grain borer	81	75	72	66	55	49	41
Sawtoothed grain beetle	86	36	12	8	2	0	0
Rust red flour beetle	65	39	35	18	11	10	5
<u>9% Wheat</u>							
Granary weevil	50	35	31	21	9	6	5
Rice weevil	21	15	14	3	3	2	1
Confused flour beetle	98	96	94	94	91	88	86
Lesser grain borer	92	88	80	75	69	65*	
Sawtoothed grain beetle	96	79	55	40	20	11	8
Rust red flour beetle	89	72	62	50	39	26	21

* Adult progeny recovered.

Effects of dockage in grain on ability of insects to breed in dry grain.

The previous experiments have been conducted with grain free from dockage, but, since it is unusual to find grain that is entirely free from dockage, the results obtained do not accurately reflect the ability of the insects classed as bran bugs to breed in grain normally found in farm storage. That bran bugs are capable of breeding in flour of very low moisture content is indicated by the data of table 23.

Table 23: -- Survival of adult flour beetles in graham flour of different moisture content at 75° F.*

Moisture content of flour	Percent survival at end of: 2 Weeks	4 Weeks	6 Weeks	Number of progeny recovered (estimated) after 6 weeks
8%	100	84	76	300 larvae -- 1 pupa
9%	94	74	66	400 " -- --
10%	84	66	66	500 " -- 50 pupae
11%	100	100	96	500 " -- 60 "
12%	100	68	58	400 " -- 40 "
13%	100	58	52	300 " -- 100 "
14%	100	80	68	200 " -- 200 "

* 50 Flour beetle adults were placed in each culture at start of test.

Additional tests are being conducted with wheat samples containing different proportions of dockage, in order to complete our information on this subject.

Tests with Various Treatments of Wooden Grain Bins to Prevent Burrowing of Grain-Infesting Insects.*

As recorded in the previous report, a number of model wooden bins 7" x 7" x 6½" were treated with various chemicals to determine whether or not any of them would be sufficiently repellent to grain-infesting insects to prevent them from burrowing into the woodwork. In June these bins were filled with wheat infested with the cadelle and the lesser grain borer. Examination was made at the end of 2, 3, and 4 months to determine what degree of protection the various treatments afforded. Data regarding the condition of the wooden bins at these three inspection periods are given in table 24.

It will be noted from the data of table 24 that, compared with the untreated wooden bins, practically all treatments exhibited some repellent properties.

* Reported by R. T. Cotton and H. D. Young.

Table 24: -- Condition of wooden bins after 2, 3, and 4 months exposure to the cadelle and the lesser grain borer.

No.	Treatment of bin	Number of holes bored in woodwork: After 2 Months	After 3 Months	After 4 Months	Remarks
1	White lead paint, 2 coats	0	0	0	
2	do	0	0	0	
3	Boiled linseed oil, 2 coats	0	0	10	
4	do	11	12	15	
5	Spar varnish, 2 coats	2	1	4	
6	do	2	2	6	
7	Nitroethane, 2 coats	4	5	22	
8	do	0	2	19	
9	K1127, 2 coats	0	1	1	
10	do	0	1	1	
11	Dowspray #208, 2 coats	0	1	1	
12	do	0	0	0	
13	Pyrofume 20, 2 coats	0	0	0	
14	do	0	0	0	
15	Lethane #385 special, 2 coats	0	0	0	
16	do	0	0	0	
17	Nicotine sulphate 40%, 1 coat	0	0	0	
18	do	0	0	0	
19	Thanite special, 2 coats	0*	0	0	*No. of insects dead
20	do	0*	0	0	do
21	Mineral oil, 2 coats	0	0	18	
22	do	0	0	22	
23	White wash, 1 coat	0	0	0	
24	do	1	1	1	
25	White paint + 10% nitroethane, 1 coat	3	3	3	
26	do	0	1	3	
27	White paint + 10% K1127, 1 coat	0	3	6	
28	do	1	3	4	
29	White paint + 10% Dowspray 208, 1 coat	0	0	5	
30	do	0	2	4	
31	White paint + 10% Pyrofume 20, 1 coat	0	0	1	
32	do	0	12	12	
33	White paint + 10% Lethane 384, 1 coat	2*	3	4	2 in unpainted spots
34	do	0	3	4	
35	White paint + 10% Nicotine sulphate 40% 1 coat	0	0	3	
36	do	0	1	5	
37	White paint + 10% Thanite, 1 coat	6*	6*	6	6 in unpainted spots
38	do	0	1	2	
39	White paint + 10% oil wintergreen, 1 coat	1	6	10	
40	do	0	1	8	
41	White paint + 10% anise, 1 coat	1	2	4	
42	do	4	3	8	

Table 24 continued

No.	Treatment of bin	Number of holes bored in woodwork: After 2 Months	After 3 Months	After 4 Months	Remarks
43	Mineral oil + 10% Lethane 384, 1 coat	7	4	18	
44	do	0	1	1	
45	Mineral oil + 10% Pyrofume 20, 1 coat	1	3	5	
46	do	0	1	3	
47	Mineral oil + 10% Nicotine sulphate, 1 coat	1	0	0	
48	do	0	0	0	
49	Melted paraffin	2	1	8	
50	do	1	2	25	
51	do	5	2	20	
52	do	2	3	12	
53	1% in water of nicotine sulphate 40%	10	10	17	
54	do	6	6	15	
55	Check, untreated	12	15	30-40	
56	do	16	20-30	30-40	
57	do	10	20-30	30-40	
58	do	10	20-30	30-40	
59	do	15	20-30	30-40	
60	do	11	20-30	30-40	
61	Termi-tox concentrate, 1 coat	0*	0	0	Examined 8/15/42
62	do	0*	0	0	do
63	1 Pt. Termi-tox conc. 4 pts. naphtha	0*	0	0	do
64	do	1*	1	1	do
67	5 Plywood	*	20	29	Started 8/15/42
68	do		18	37	

Wooden bins constructed on the experimental storage site at Hutchinson, Kansas, have been treated with white wash, white lead, nicotine sulphate, Dowspray 208, and K1127 to test the effect of these materials in preventing insect damage to the woodwork of bins under actual storage conditions.

Insect Pests of Soy Beans*

A large group of insects classed as stored product insects feed on almost any type of dried vegetable material that is available, and is in a physical condition suitable for food. Soy beans are no exception and are likely to be attacked in storage by many of the general feeders included in this class of insect pests. The Indian meal moth, Plodia interpunctella Hbn., (1 and 2), the fig moth, Ephestia cautella Walk., (3), and Aphomia gularis Zeller (4), have all been reported as breeding in soy beans and it is probable that other species belonging to this group of moths are quite capable of breeding in the beans equally as well.

A number of Bruchids are capable of breeding in soy beans. Bridwell (5) reported the breeding of Bruchus chinensis and B. quadrimaculatus from soy beans, also an undetermined Bruchid close to B. ornatus that he refers to as the Dolichos weevil and another species that he states is probably Spermophagus (Zabrotes) pectoralis Sharp. Zacher (6) reported Spermophagus subfasciatus Boh. developing in soy beans. Several writers report, however, that soy beans are immune to the attack of Acanthoscelides obtectus Say. DeBussy (7) reported the cigarette beetle Lasioderma serricorne as a pest of stored soy beans and Goidanich (8) reported the infestation of a 6000 ton shipment of soy beans heavily infested by the Nitidulid Meligethes aeneus F. Larval mines in the soy beans resembled those made by Bruchids.

Mites also appear to be capable of breeding in soy beans and Belyaev, Shesterikova and Popov (9) record Tyroglyphus farinae, T. dimidiatus and T. mycophagus as damaging soy bean seeds.

In order to determine which, if any, of our common stored grain insects are capable of attacking soy beans in storage, a preliminary set of tests were started on June 10, 1942. Eight species of insects were tested by placing a given number in a quart jar with one pound of soy beans. Since the moisture content of the soy beans that were available for the experimental work was only 7%, water was added to bring the moisture content up to 14% before adding the adult insects. Wherever sufficient insects were available, two lots of soy beans were tested for each species. In one lot only whole uninjured beans were used, and in the second lot the beans were cracked to provide a high percentage of chaff and small particles. The jars containing the soy beans and insects were kept in the laboratory basement, where the daily mean temperature fluctuated between 75 and 80° F.

Examinations were made at monthly intervals and the number of live and dead insects, as well as any evidence of reproduction, were recorded. Results of these monthly examinations are summarized in table 25.

1. Cowpea weevil _Callosobruchus maculatus_

The cowpea weevil, a common pest of dry beans used in these tests were obtained from samples of infested Mung beans. Thirty adults were placed in the jar with one pound of soy beans. At the end of one month six adults were still alive, all of which were dead at the end of the second month. A small amount of feeding was observed. At the end of the third month, one live and 54 dead adults were found, all of which were progeny of the original adults. Characteristic emergence holes were found in the soy beans giving adequate proof that these specimens had developed therein.

2. Cadelle _Tenebroides mauritanicus_

One month after the tests were started several very small cadelle larvae were found in the sample of soy beans infested with 20 cadelle adults. At this time a considerable number of eggs were found. Subsequent examinations failed to reveal life, the larvae observed in the first examination having died while still quite young. Fourteen of the original 20 adults were alive after one month, but all were dead at the end of the second month. Some feeding by the adult cadelle took place, but apparently the food would not permit the development of the larvae.

3. Rice weevil _Sitophilus oryza_

None of the adult rice weevil were alive at the time of the first examination in either the cracked or whole soy bean samples infested with this species. Examinations during August and September revealed no life, indicating definitely that the rice weevil did not reproduce in these samples.

4. Granary weevil _S. granarius_

Samples of soy beans infested with this species contained live adults in both the cracked and whole bean lots, at the end of the first month. All were dead, however, at the end of the second month, and subsequent examination showed that no reproduction had taken place.

5. Lesser grain borer _Rhizopertha dominica_

In the sample of cracked soy beans all adult lesser grain borers were dead at the end of one month. Twelve were still alive in the whole bean sample at this time, but these had all died by the end of the second month. No reproduction took place in either sample.

6. Sawtoothed grain beetle *Oryzaephilus surinamensis*

This species was able to exist in the sample of cracked soy beans. At the end of the first month 86 of the original 100 adults were still alive, 50 at the end of the second month, and 17 at the end of the third month. However, in the sample of whole soy beans, only 4 were alive at the end of the first month, all of which were dead at the end of the second month.

At the end of the first month a considerable number of very small larvae were observed in the cracked soy bean sample. Subsequent examinations showed that all had died, none completing development to the adult stage. At the second and third examinations no live larvae were found.

7. Confused flour beetle *Tribolium confusum*

Of the eight species of insects used in these tests, the confused flour beetle appeared to be the only one which was able to survive in a high degree on soy beans. Of the 200 adults placed in the jar of cracked soy beans, 176 were alive at the end of one month, 156 were alive at the end of the second month, and 114 were alive at the end of the third month. Of the latter, however, some were adult progeny of the original adults tested. In the sample of whole soy beans, 103 were alive at the end of the first month, 85 at the end of the second month and 26 at the end of the third month.

A considerable number of small larvae were observed in the cracked soy bean sample at the end of the first month, some of which had died by the end of the second month. Others had continued development, but none had reached the pupa stage. At the end of the third month, 40 individuals had completed development, and a considerable number of larvae were in the sample. No reproduction had taken place in the sample containing whole soy beans as food. Although this species is able to exist and reproduce in soy beans, providing there is a considerable amount of dockage present, conditions for its development are apparently not very favorable.

8. Mediterranean flour moth *Ephestia kuehniella*

Owing to the short life of adults of this species, all were dead at the end of the first month. No signs of reproduction, however, were noted until the end of the second month, when a few small larvae were found in both the cracked and whole soy bean samples. At the end of the third month 8 live larvae and 1 live pupa were recovered from the sample of cracked soy beans, and 2 live adults and 3 live larvae were recovered from the whole soy bean sample. The latter also had 4 dead adults.

This species ordinarily completes its life cycle in flour in from 8 to 9 weeks, hence the slow development and small numbers completing the life cycle indicate that the soy bean is not well suited as a food for the Mediterranean flour moth.

Table 25: -- Summary of preliminary feeding tests with soy beans. Insects placed with soy beans June 10, 1942.

Insect	Number used	Type of food	Condition of Insects					
			July		August		September	
			Alive	Dead	Alive	Dead	Alive	Dead
Cowpea weevil	30	Whole soybean	6	24	0	6	1	54
Cadelle	20	" " "	14	6	0	14	0	0
Rice weevil	100	Cracked "	0	100	-	-	-	-
" "	100	Whole "	0	100	-	-	-	-
Granary weevil	100	Cracked "	9	91	0	9	-	-
" "	100	Whole "	9	91	0	9	-	-
Lesser grain borer	100	Cracked "	0	100	-	-	-	-
" " "	100	Whole "	12	88	0	12	-	-
Sawtoothed grain beetle	100	Cracked "	86	14	50	36	17	33
" " "	100	Whole "	4	96	0	4	-	-
Confused flour beetle	200	Cracked "	176	24	156	20	114	82
" " "	200	Whole "	103	97	85	18	26	59
Mediterranean flour moth	30	Cracked "	0	30	0	0	9	0
" " "	30	Whole "	0	30	0	0	5	4

1. Nakayama, S. Some Observations on the Breeding of Plodia interpunctella Hubn. J. Plant Prot. 26, No. 1, pp. 8-11, Tokyo, Jan. 1939.

2. Tosi, R. A Contribution to the Knowledge of Two Grain Moths. Boll. Lab. Ent. Bologna ii, pp. 292-300 Bologna, 1929.

3. Shibuya, M. On the Method of Mass-production of Trichogramma. Proc. imp. Acad. Tokyo IX, No. 3, pp. 130-133. Tokyo, March, 1933.

4. Müller, H. Der Samenzunsler Paralispa (Aphomia) gularis. Zeller und Seine Bekämpfung. Anz. Shadlingsk. 15 pt. 5, pp. 51-56, Berlin, 1939.

5. Bridwell, J.C. Notes on the Bruchidae and Their Parasites in the Hawaiian Islands. Proc. Hawaiian Entom. Soc. for Year 1917. Honolulu iii, No. 5, April, 1938, pp. 465-505.

6. Zacher, F. The Choice of Food and Biology of Reproduction in Seed-infesting Beetles. Anz. Schadlingsk, IV, No. 11, pp. 148, Berlin, November, 1928.

7. DeBussy, L.P. Lasioderma in Deli and Methods of Combating it. Meded. Deli Proefstation, Medan X, No. 6, July, 1917, pp. 129-160.

8. Goidanich, A. Beetles Imported in Ships. Boll. Soc. Ent. ital., lix, No. 3, pp. 46-48, Genoa, March, 1927.

9. Belyaev, I. M., Shesterikova, M. N., and Popov, P. V. Materials for the Study of Pests of Stored Oil Seed. Schr. Zent. biochem. Forsch. Inst. Nahrungs-u Genussmittelnid 1, No. 8, pp. 344-432, Moscow, 1932.